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Failure of the Ghana Law School Building in Accra, Ghana

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Theme I

Case Histories in Foundations of Structures and Failure Records

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SYNOPSIS: The immediate post-independence era in Ghana, namely the late 1950's to early 1960's, was characterised by extensive physical and infrastructural development, for most of which proper design and construction records were either not kept or were lost. This has often led to difficulties when remedial measures have to be designed for some of these structures which have failed after only a few years in service. The paper describes attempts to diagnose the cause(s) of failure and to design remedial measures for one such structure in the absence of original construction records.

INTRODUCTION

As is the case in many developing countries, the immediate post - independence era in Ghana was characterised by extensive physical and infrastructural development, the design and construction of which were sometimes undertaken in haste, sometimes resulting in failure to keep proper design and construction records. This has often led to difficulties when remedial measures have to be designed later in the event of a failure.

The foundation failure of the classroom block of the Ghana Law School in Accra was one of the more spectacular case histories of structural failure in Accra. Completed in 1960, this 4-storey reinforced concrete framed structure began to show signs of structural distress after only two years of use, with the appearance of large cracks, and the accelerated widening of expansion joints. By 1964, the extent of structural distress was such as a warrant the declaration of the structure as unfit for human occupation, following the occurrence of a minor earthquake (M=4) in Accra on March 11, 1964. Subsequent detailed geotechnical investigations and field measurements enabled the causes of structural distress to be identified as differential foundation movement and proper remedial measures designed.

The paper discusses the details of the investigations carried out in the process of working out appropriate remedial measures in the absence of adequate information on the planning, design and construction of the structure.

DESCRIPTION OF THE STRUCTURE

The Ghana Law School Buildings are located in Central Accra, close to the Parliament and the Supreme Court Buildings. This part of Accra is generally flat with very poor natural drainage, although the actual site is moderately drained and slopes gently to the north-west.

The Buildings comprise a 4-storey Classroom Block measuring 38m long by 9m wide and aligned in the east-west direction and a 23m long Lecture Hall which is two storeys high. The two structures are of conventional reinforced concrete framed construction arranged in an L shape.

The classroom block itself was divided into three units, (units A, B, C), separated by the stairwells which were simply supported by adjacent units on 9cm wide cantilevered sliding joint supports. The three units were separated at the roof level by expansion joints.

The ten reinforced concrete structural frames, spaced at about 4.6m centres, were carried on independent transverse 1.5m wide strip footings placed at an average depth of 1.5m below existing ground level. The structural frames did not appear to be adequately tied together in the lateral direction, thus resulting in a rather flexible structure, which could easily undergo differential movements due to settlement or heave of the foundation.

GEOLOGICAL SETTING

The urban geology and the mode of formation and geotechnical engineering properties of the foundation soils of Accra have been discussed in detail by Harris (1970), Bhatia (1968) and Kumapley (1982), among others.

The city is underlain by three main rock types, namely the ACCRAIAN series, of Devonian age, consisting of sandstones and shales covering most of central Accra, including the site of the Law School, with the older (pre-Cambrian) TOGO quartzites and the DAHOMEYAN gneisses and schists occurring to the east, north, and west of the city. The solid geology is, however, often obscurred by either residual lateritic soils or recent alluvial deposits laid down by the numerous rivers and lagoons in the low-lying areas of the city.

The site under consideration is underlain by the clay shales of the Accraian series. These weather into potentially highly expansive residual clays whose general geotechnical engineering properties have been discussed in some detail by de Graft-Johnson et al (1967, 1973).

Many geologic faults have been mapped or inferred within the city. The general project area is on the downthrow side of a major observed NE-SW trending fault, while another inferred fault passes close by the site.

FIELD INVESTIGATIONS

The field investigations for diagnosing the cause(s) of structural distress consisted of a detailed damage survey of the classroom block and the surrounding structures, a description of the prevailing condition of the site drainage facilities and detailed geotechnical investigations to determine the nature and properties of the foundation soils. The investigations were carried out between January and April of 1965.

Description of Damage

While damage to the two-storey high Lecture Hall was minor, being limited essentially to scattered hair line cracks, the classroom block experienced extensive cracking damage, and considerable distortion within the structural frames. The resulting structural damage was concentrated within the lower two storeys and at the junctions between the stairwells and the adjacent units. Of the three units into which the classroom block was divided, units B and C were the most heavily damaged, and Unit A the least damaged. Fig 1 shows the condition of the damaged structure in the vicinity of the stairwell between units B and C.

Fig. 1 General View of Classroom Block Before Rehabilitation.Note cracks at contact between Unit B and Stairwell.

In the absence of information on the original floor levels and the locations and elevations of original construction bench marks, it was impossible to determine absolute magnitudes of vertical movements. However, based on the assumption that the finished floors were originally level, precise levelling was employed to establish that the central part of the classroom block had heaved by about 80mm with respect to the edges. Furthermore, tilt measurements, made by lining up the columns with a theodolite, showed that the structural frames had undergone maximum angular distortions ranging from 1/280 in Unit C to 1/720 in Unit B. The general distortion pattern of the whole structure is shown in Fig. 2. It is interesting to note that the threshold angular distortion for cracking damage to framed structures has been estimated at 1/500 by both Burland et al (1975) and Skempton et al (1956).

A detailed damage survey of major structures in the vicinity of the Ghana Law School showed that the extent of cracking damage varied from mild to severe in the cases of the Parliament House and the abandoned structure formerly used as the Domestic Science Building of a nearby Girls School. The Supreme Court Buildings also showed evidence of having undergone periodic extensive repairs for cracking damage.

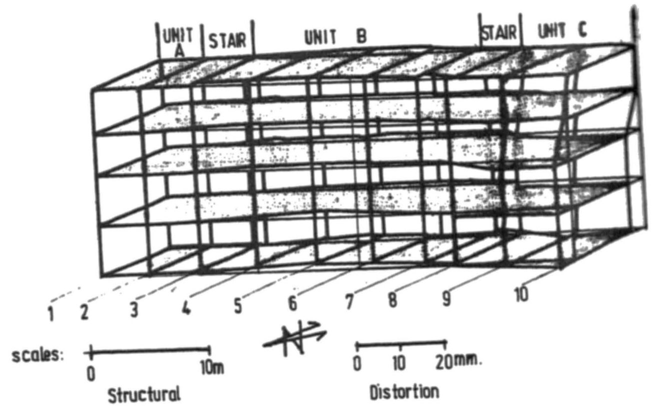

Fig. 2 General Distortion Pattern of Structure.

Site Drainage Conditions

At the time of the investigations, the surface drainage facilities were generally in a poor state of repair, as shown in Fig. 3. The concrete storm drain running alon the north side of the classroom building was cracked in many places, thus permitting ingress of water into the foundation soil. There was also some evidence that con siderable leakage was occurring from the ornamental pon in front of the classroom block. General ponding of sections of the site was noticed, even though the inves tigations were carried out during the dry season. The Accra area experiences two rainy seasons in a year, the main season reaching its peak in May-June and the minor one in October. The driest period of the year is from January to April, when the soils attain their most dessicated state.

Geotechnical investigations

A detailed programme of geotechnical investigations, consisting of geophysical surveys and the drilling of a total of 16 borings using the power auger, percussion and rotary drilling down to a depth of 25m, failed to reveal any abrupt changes within the subsurface profile to indicate any evidence of major faulting at the site. The locations of the various borings are shown in Fig. while a typical sub-soil profile along section C-C,' shows that the foundations of the classroom block were placed on three types of material, namely the fresh and the decomposed clay shale and the so-called "channel deposit" consisting of a highly permeable formation of gravels in an expansive clay matrix, up to 2m thick, which appears to have been laid down in a buried channel sometime past.

The origin of the "buried channel" which was about 15m wide and trends approximately NW-SE was obscure. The channel was too shallow to justify any association with geologic faults, and in any case, it had already been established that the site was essentially free of major faulting. Even though the local name for this part of the city - Kimbu - suggested the existence of a gully or creek, reference to the oldest readily available map of the area (circa 1911) failed to reveal any evidence of major topographic features. However, the substantia thicknesses of random fill encountered in the borings suggested some attempt at reclamation in the past; a fac which would tend to reinforce the widely held view that the channel represented an old stream bed.

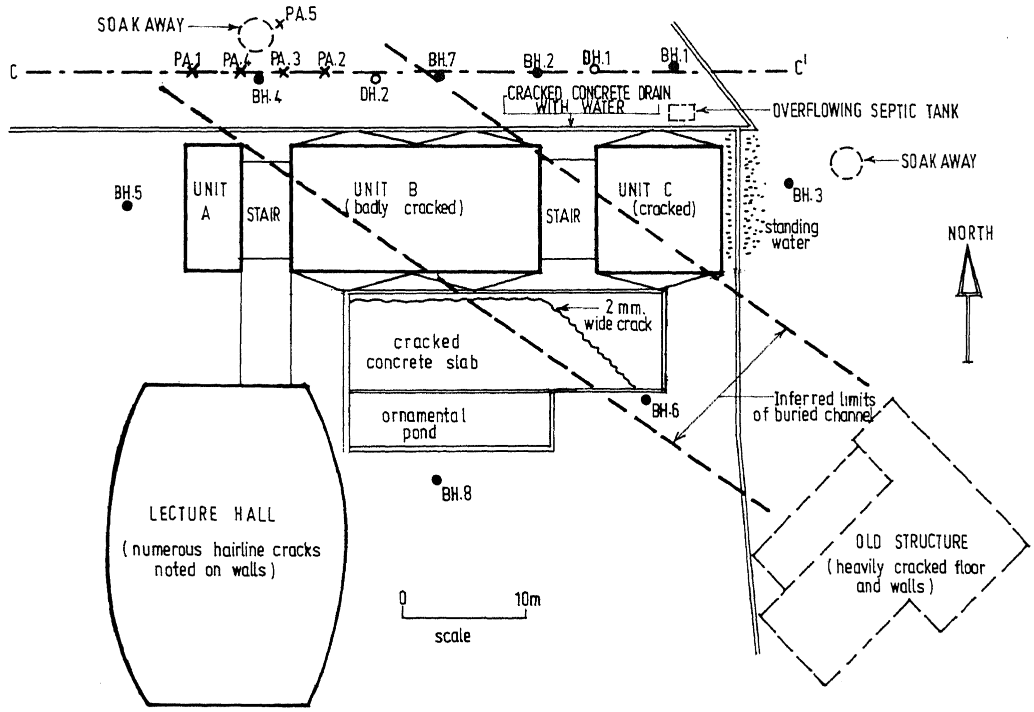

Fig. 3 Details of Fieldwork

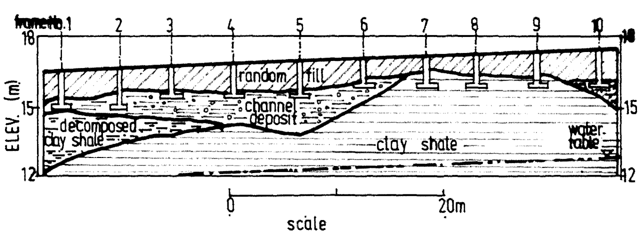

Fig. 4 Typical Sub-Surface Profile

Ground water levels were recorded at depths of between 5.5m and 6.1m below existing ground level. The investigations were carried out during the dry season, but given the relatively impermeable nature of the decomposed clay shale, it is unlikely that groundwater levels would change appreciably during the wet season. The chances of the natural groundwater level rising to the foundation level were therefore considered minimal.

Typical Geotechnical Properties.

Both the "channel deposit" and the decomposed clay shale have typical liquid limits and plasticity indices of 60% and 35% respectively. The relatively wide difference in the particle size distributions of the two soil types is, clearly shown in Fig. 5.

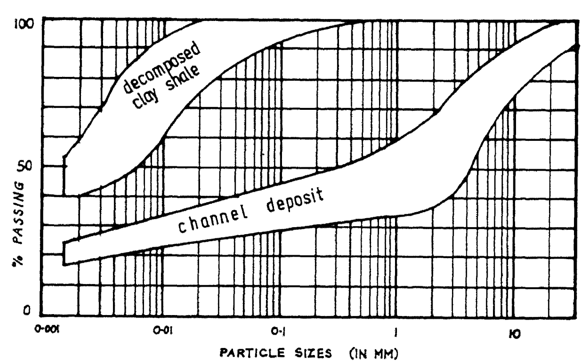

Fig. 5 Particle Size Distribution Ranges for Decomposed Clay Shale and "Channel Deposit".

Tests by Kwami (1975) showed that both the clay matrix of the channel deposit and the decomposed clay shale are capable of exerting maximum swell pressure of about 300 kN/m^2 which compares favourably with the value of 325 kN/m^2 reported by Anon (1965) for the clay shale at an initial moisture content of 15%.

Causes of foundation failure

The investigation have established the cause of structural distress as differential foundation heaving due to saturation of the "channel deposits", access to water being caused by poorly maintained surface drainage facilities and the inadvertent siting of one of the main soakaways within the buried "channel" (Fig. 3). A test hole (PA 5) located near this soakaway showed that the surrounding soil was waterlogged from a depth of 2m, when the general groundwater table in the area was at a depth of about 5m.

REMEDIAL MEASURES

The remedial measures adopted for the rehabilitation of the structure included;

(i) the partial underpinning of the structure to facilitate the extension of the affected footings to a total depth of about 4m to ensure that they are placed on the clay shale rather than on the channel deposits. All the columns, mainly of units B and C, falling with the inferred limits of the buried channel were underpinned. This aspect of the work was carried out with the usual precautions of monitoring movements in the superstructure, especially the installation of tell-tales across major cracks to indicate sudden movements (Fig. 6). Except for the excavations for footings close to the soakaway in which major groundwater seepage was noted, most of the excavation was carried out under conditions of minimal groundwater seepage, although the excavated material was in a moist state.

Fig. 6 Typical Arrangement for Monitoring Crack Movement During Underpinning

(ii) a complete re-design of the two stairwells to separate them from the adjacent units and to place them on new footings, also carried through the channel deposits on to the clay shale.

(iii) general repair and improvement of the surface drainage provisions.

CONCLUDING REMARKS

It was doubtful whether any geotechnical investigations were carried out prior to the construction of the structure, hence the existence of the channel was therefore probably not known of.

The rehabilitated structure has been in regular use since 1978 and has been performing satisfactorily. Availability of detailed design and original construction records and "as - built" drawings would have considerably reduced the time between evacuating and rehabilitating the structure, and would certainly have reduced the extent of the diagnostic investigations, thus leading to major cost savings.

ACKNOWLEDGEMENT

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